

Explaining $B \rightarrow K\pi$ anomaly with non-universal Z' boson

R. Mohanta¹ and A. K. Giri²

¹ *School of Physics, University of Hyderabad, Hyderabad - 500 046, India*

² *Department of Physics, Punjabi University, Patiala - 147 002, India*

Abstract

We study the effect of non-universal Z' boson in the decay modes $B \rightarrow K\pi$. In the standard model these modes receive dominant contributions from $b \rightarrow s$ QCD penguins. Therefore, in this limit one expects $S_{\pi^0 K^0} \approx \sin 2\beta$, $A_{\pi^0 K^0} \approx 0$ and $A_{\pi^0 K^-} \approx A_{\pi^+ K^-}$. The corrections due to the presence of small non-penguin contributions is found to yield $S_{\pi^0 K^0} > \sin 2\beta$ and $\Delta A_{CP}(K\pi) \simeq 2.5\%$. However, the measured value of $S_{\pi^0 K^0}$ is less than $\sin 2\beta$ and $\Delta A_{CP}(K\pi) \simeq 15\%$. We show the model with a non-universal Z' boson can successfully explain these anomalies.

PACS numbers: 11.30.Er, 12.60.Cn, 13.25.Hw

The standard model (SM) of electroweak interaction is very successful in explaining the observed data so far, but still it is believed that there must exist some new physics beyond the SM, whose true nature is not yet well-known. Therefore, intensive search for physics beyond the SM is now being performed in various areas of particle physics. In this context the B system can also be used as a complementary probe. One of the important ways to look for new physics in the b -sector is the analysis of rare B decay modes, which are induced by the flavor changing neutral currents (FCNCs), in particular $b \rightarrow s$ transitions. Although, so far we have not been able to see any clear indication of physics beyond the SM in the currently running B -factories but there appears to be some kind of deviation in some $b \rightarrow s$ penguin induced transitions i.e., the mixing induced CP asymmetries in many $b \rightarrow s\bar{q}q$ penguin dominated modes do not seem to agree with the SM expectations. The measured values in such modes follow the trend $S_{s\bar{q}q} < \sin 2\beta$ [1], whereas in the SM they are expected to be similar [2]. In this context $B \rightarrow K\pi$ decay modes, which receive dominant contributions from $b \rightarrow s$ mediated QCD penguins in the SM, provide an ideal testing ground to look for new physics.

At present, there seems to be two possible hints of new physics in these modes. The first one is associated with the mixing induced CP asymmetry in $B^0 \rightarrow \pi^0 K^0$ mode. The time dependent CP asymmetry in this mode is defined as

$$\frac{\Gamma(\bar{B}^0(t) \rightarrow \pi^0 K_s) - \Gamma(B^0(t) \rightarrow \pi^0 K_s)}{\Gamma(\bar{B}^0(t) \rightarrow \pi^0 K_s) + \Gamma(B^0(t) \rightarrow \pi^0 K_s)} = A_{\pi^0 K_s} \cos(\Delta M_d t) + S_{\pi^0 K_s} \sin(\Delta M_d t), \quad (1)$$

and in the pure QCD penguin limit one expects $A_{\pi^0 K_s} \approx 0$ and $S_{\pi^0 K_s} \approx \sin(2\beta)$. Small non-penguin contributions do provide some corrections to these asymmetry parameters and it has been shown in Refs. [3, 4, 5, 6] that these corrections generally tend to increase $S_{K\pi^0}$ from its pure penguin limit of $(\sin 2\beta)$ by a modest amount i.e., $S_{\pi^0 K_s} \approx 0.8$. Recently, using isospin symmetry it has been shown in [7, 8] that the standard model favors a large $S_{\pi^0 K_s} \approx 0.99$.

However, the recent results from Belle [9] and Babar [10] are

$$\begin{aligned} A_{\pi^0 K_s} &= 0.14 \pm 0.13 \pm 0.06, & S_{\pi^0 K_s} &= 0.67 \pm 0.31 \pm 0.08 & (\text{Belle}) \\ A_{\pi^0 K_s} &= -0.13 \pm 0.13 \pm 0.03, & S_{\pi^0 K_s} &= 0.55 \pm 0.20 \pm 0.03 & (\text{Babar}) \end{aligned} \quad (2)$$

with average

$$A_{\pi^0 K_s} = -0.01 \pm 0.10, \quad S_{\pi^0 K_s} = 0.57 \pm 0.17, \quad (3)$$

where $S_{\pi^0 K_s}$ is found to be smaller than the present world average value of $\sin 2\beta = 0.672 \pm 0.024$ measured in $b \rightarrow c\bar{c}s$ transitions [1] by nearly 1-sigma.

This deviation which is opposite to the SM expectation, implies the presence of new physics in the $B^0 \rightarrow K^0 \pi^0$ decay amplitude. In the SM, this decay mode receives contributions from QCD penguin (P), electroweak penguin (P_{EW}) and color suppressed tree (C) diagrams, which follow the hierarchical pattern $P : P_{EW} : C = 1 : \lambda : \lambda^2$, where $\lambda \approx 0.2257$ is the Wolfenstein expansion parameter. Thus, accepting the above discrepancy seriously one can see that the electroweak penguin sector is the best place to search for new physics.

The second anomaly in the $B \rightarrow K\pi$ sector is associated with the direct CP asymmetry parameters of $B^- \rightarrow \pi^0 K^-$ and that of the $\bar{B}^0 \rightarrow \pi^+ K^-$. The $\Delta A_{CP}(K\pi)$ puzzle refers to the difference in direct CP asymmetries in $B^- \rightarrow \pi^0 K^-$ and $\bar{B}^0 \rightarrow \pi^+ K^-$ modes. These two modes receive similar dominating contributions from tree and QCD penguin diagrams and hence one would naively expect that these two channels will have similar direct CP asymmetries i.e., $A_{\pi^0 K^-} \approx A_{\pi^+ K^-}$. In the QCD factorization approach, the difference between these asymmetries is found to be [11]

$$\Delta A_{CP} = A_{K^-\pi^0} - A_{K^-\pi^+} = (2.5 \pm 1.5)\% \quad (4)$$

whereas the corresponding experimental value is [1]

$$\Delta A_{CP} = (14.8 \pm 2.8)\% , \quad (5)$$

which yields nearly 4σ deviation. This constitutes what is called $\Delta A_{CP}(K\pi)$ puzzle in the literature and is believed to be an indication of the existence of new physics.

To account for these discrepancies between the observed and expected observables, here we consider the effect due to an extra $U(1)'$ gauge boson Z' as an illustration, which can provide additional contributions to the electroweak penguin sector. The existence of extra Z' boson is a feature of many models addressing physics beyond the SM, e.g., models based on extended gauge groups characterized by additional $U(1)$ factors [12]. Also the new physics models which contain exotic fermions, predict the existence of additional gauge boson [13]. Flavor mixing can be induced at the tree level in the up-type and/or down-type quark sector after diagonalizing their mass matrices.

Before incorporating the effect of extra Z' boson to the $B \rightarrow K\pi$ amplitudes, first we would like to briefly present the standard model results. In the SM, the relevant effective

Hamiltonian describing the decay modes $\bar{B} \rightarrow \pi \bar{K}$ is given by

$$\mathcal{H}_{eff}^{SM} = \frac{G_F}{\sqrt{2}} \left[V_{ub} V_{us}^* (C_1 O_1 + C_2 O_2) - V_{tb} V_{ts}^* \sum_{i=3}^{10} C_i O_i \right]. \quad (6)$$

Thus, one can obtain the transition amplitudes in the QCD factorization approach [14] as

$$\begin{aligned} \sqrt{2} A(\bar{B}^0 \rightarrow \pi^0 \bar{K}^0) &= \lambda_u A_{\bar{K}\pi} \alpha_2 \\ &+ \sum_{p=u,c} \lambda_p \left[A_{\pi \bar{K}} \left(-\alpha_4^p + \frac{1}{2} \alpha_{4,EW}^p - \beta_3^p + \frac{1}{2} \beta_{3,EW}^p \right) + \frac{3}{2} A_{\bar{K}\pi} \alpha_{3,EW}^p \right], \end{aligned} \quad (7)$$

$$\begin{aligned} \sqrt{2} A(B^- \rightarrow \pi^0 K^-) &= \lambda_u \left(A_{\pi \bar{K}} (\alpha_1 + \beta_2) + A_{\bar{K}\pi} \alpha_2 \right) \\ &+ \sum_{p=u, c} \lambda_q \left(A_{\pi \bar{K}} (\alpha_4^p + \alpha_{4,EW}^p + \beta_3^p + \beta_{3,EW}^p) + \frac{3}{2} A_{\bar{K}\pi} \alpha_{3,EW}^p \right) \end{aligned} \quad (8)$$

and

$$A(\bar{B}^0 \rightarrow \pi^+ K^-) = \lambda_u A_{\pi \bar{K}} \alpha_1 + \sum_{p=u, c} \lambda_q A_{\pi \bar{K}} \left(\alpha_4^p + \alpha_{4,EW}^p + \beta_3^p - \frac{1}{2} \beta_{3,EW}^p \right), \quad (9)$$

where $\lambda_p = V_{pb} V_{ps}^*$ and

$$A_{\pi \bar{K}} = i \frac{G_F}{\sqrt{2}} M_B^2 F_0^{B \rightarrow \pi} f_K, \quad A_{\bar{K}\pi} = i \frac{G_F}{\sqrt{2}} M_B^2 F_0^{B \rightarrow K} f_\pi. \quad (10)$$

The parameters α_i 's and β_i 's are related to the Wilson coefficients C_i 's and the corresponding expressions can be found in [14].

Thus, one can symbolically represent this amplitude as

$$A(\bar{B} \rightarrow \pi \bar{K}) = \lambda_u A_u + \lambda_c A_c = \lambda_c A_c \left[1 + r a e^{i(\delta_1 - \gamma)} \right], \quad (11)$$

where $a = |\lambda_u / \lambda_c|$, $-\gamma$ is the weak phase of V_{ub} , $r = |A_u / A_c|$, and δ_1 is the relative strong phases between A_u and A_c . From the above amplitude, the CP averaged branching ratio, direct and mixing induced CP asymmetry (for neutral B meson case) parameters can be obtained as

$$\begin{aligned} \text{Br} &= \frac{|p_{c.m}| \tau_B}{8\pi M_B^2} |\lambda_c A_c|^2 (1 + (ra)^2 + 2ra \cos \delta_1 \cos \gamma), \\ A_{\pi K} &= \frac{2r a \sin \delta_1 \sin \gamma}{1 + (ra)^2 + 2ra \cos \delta_1 \cos \gamma}, \\ S_{\pi K} &= \frac{\sin 2\beta + 2ra \cos \delta_1 \sin(2\beta + \gamma) + (ra)^2 \sin(2\beta + 2\gamma)}{1 + (ra)^2 + 2ra \cos \delta_1 \cos \gamma}. \end{aligned} \quad (12)$$

For numerical evaluation, we use input parameters as given in the S4 scenario of QCD factorization approach [14]. For the CKM matrix elements we use $V_{cb} = (41.5^{+1.0}_{-1.1}) \times 10^{-3}$, $|V_{cs}| = 0.97334 \pm 0.00023$, $|V_{ub}| = (3.59 \pm 0.16) \times 10^{-3}$, $|V_{us}| = 0.2257 \pm 0.0010$ [15] and $\gamma = (65 \pm 10)^\circ$. The particle masses and life time of B^0 are taken from [15]. Since QCD factorization suffers from end-point divergences we have included 20% uncertainties in the branching ratio and 10 % uncertainties in the CP asymmetry parameters. With these inputs we show in Figure-1 the correlation plots between the branching ratio and $S_{\pi^0 K_s}$ (left panel) and between $S_{\pi^0 K_s}$ and $A_{\pi^0 K_s}$ (right panel). From these figures it can be seen that the obtained value $A_{\pi^0 K_s}$ is in accordance with the SM expectation. However, although the SM result of $S_{\pi^0 K_s}$ lies within its observed $1 - \sigma$ range, but the branching ratio is well below the corresponding observed value. Hence the present situation is that, it appears difficult to accommodate simultaneously these three observables in the standard model.

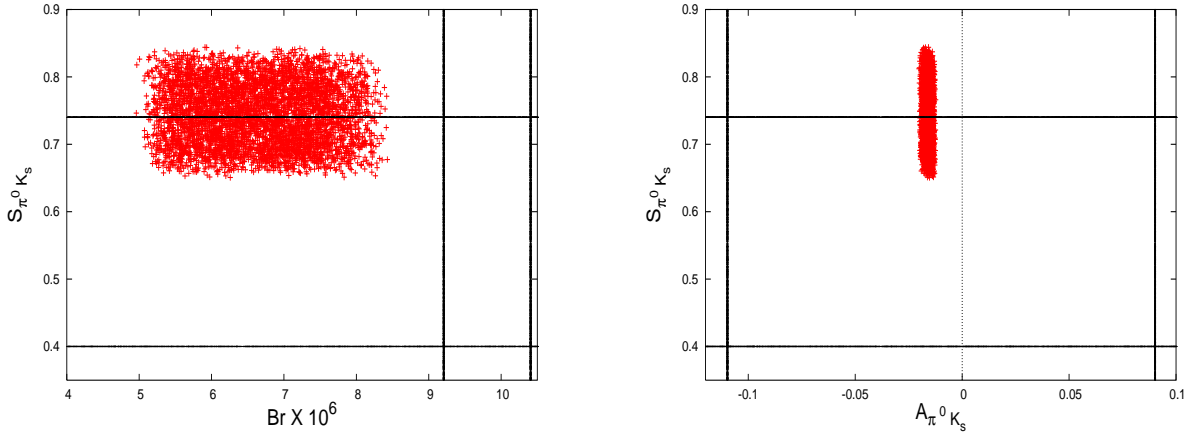


FIG. 1: Correlation plots between the mixing induced CP asymmetry $S_{\pi^0 K_s}$ and the CP averaged BR (left panel) and $S_{\pi^0 K_s}$ and the direct CP asymmetry $A_{\pi^0 K_s}$ (right panel) for the $B^0 \rightarrow \pi^0 K_s$ in the Standard Model. The horizontal and vertical lines in both the figures represent the $1 - \sigma$ allowed ranges of the respective observables.

Now we will consider the effect of the non-universal Z' boson on these decay modes $B \rightarrow \pi K$. As discussed earlier, the FCNCs due to Z' exchange can be induced by mixing among the SM quarks and the exotic quark which have different Z' quantum numbers. Here we will consider the model in which the interaction between the Z' boson and fermions are flavor nonuniversal for left handed couplings and flavor diagonal for right handed couplings. The detailed description of the family nonuniversal Z' model with flavor changing neutral

currents can be found in Ref. [12]. The search for the extra Z' boson occupies an important place in the experimental programs of the Fermilab Tevatron and CERN LHC [19]. The implications of the FCNC mediated Z' boson effect has been extensively studied in the context of B physics [16, 17, 18, 20, 21].

The effective Hamiltonian describing the transition $b \rightarrow s\bar{q}q$, where $q = u, d$ for $\bar{B} \rightarrow \pi\bar{K}$, mediated by the Z' boson is given by [17]

$$\mathcal{H}_{eff}^{Z'} = \frac{2G_F}{\sqrt{2}} \left(\frac{g'M_Z}{g_1 M_{Z'}} \right)^2 B_{sb}^L (\bar{s}b)_{V-A} \sum_q [(B_{qq}^L (\bar{q}q)_{V-A} + B_{qq}^R (\bar{q}q)_{V+A})], \quad (13)$$

where $g_1 = e/(\sin\theta_W \cos\theta_W)$, g' is the gauge coupling constant of the $U(1)'$ group and $B_{ij}^{L(R)}$ denote the left (right) handed effective Z' couplings of the quarks i and j at the weak scale. The diagonal elements are real due to the hermiticity of the effective Hamiltonian but the off diagonal elements may contain effective weak phase. Therefore, both the terms in (13) will have the same weak phase due to B_{sb}^L .

Since the structure of the effective Hamiltonian (13) in this model has the same form as that of the SM, the effect of Z' can be represented as a modification of the SM Wilson coefficients of the corresponding operators. Assuming that $B_{uu}^{L(R)} \simeq -2B_{dd}^{L(R)}$, so that the new physics is primarily manifest in the EW penguins [17], the resulting effective Hamiltonian at the M_W scale is given as

$$\begin{aligned} \mathcal{H}_{eff}^{Z'} &= -\frac{4G_F}{\sqrt{2}} \left(\frac{g'M_Z}{g_1 M_{Z'}} \right)^2 B_{sb}^L \sum_q [(B_{dd}^L O_9^{(q)} + B_{dd}^R O_7^{(q)})] \\ &= -\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \sum_q [\Delta C_9 O_9^{(q)} + \Delta C_7 O_7^{(q)}], \end{aligned} \quad (14)$$

where ΔC_7 and ΔC_9 are the new Wilson coefficients arising due to the extra Z' boson contributing to the electroweak penguin sector given as

$$\Delta C_9 = \left(\frac{g'M_Z}{g_1 M_{Z'}} \right)^2 \left(\frac{B_{sb}^L B_{dd}^L}{V_{tb} V_{ts}^*} \right), \quad \Delta C_7 = \left(\frac{g'M_Z}{g_1 M_{Z'}} \right)^2 \left(\frac{B_{sb}^L B_{dd}^R}{V_{tb} V_{ts}^*} \right). \quad (15)$$

For convenience we can parameterize these coefficients as

$$\Delta C_9 \equiv \xi_L = -|\xi_L|e^{i\phi_s}, \quad \Delta C_7 \equiv \xi_R = -|\xi_R|e^{i\phi_s}, \quad (16)$$

where ϕ_s is the weak phase associated with B_{sb}^L and the minus signs in the r.h.s appear because the weak phase of the CKM element V_{ts} is π .

After having an idea about the new electroweak penguin contributions at the M_Z scale, we now evolve them to the b scale using renormalization group equation [22]. Using the values of these coefficients at b scale we obtain the new contribution to the transition amplitudes. These values can then be evolved to the m_b scale using the renormalization group equation [22]

$$\vec{C}(m_b) = U_5(m_b, M_W, \alpha) \vec{C}(M_W), \quad (17)$$

where C is the 10×1 column vector of the Wilson coefficients and U_5 is the five flavor 10×10 evolution matrix. The explicit forms of $\vec{C}(M_W)$ and $U_5(m_b, M_W, \alpha)$ are given in [22].

Because of the RG evolution these three Wilson coefficients generate new set of Wilson coefficients $\Delta C_i (i = 3, \dots, 10)$ at the low energy regime (i.e., at the m_b scale) as presented in Table-1.

ΔC_3	ΔC_4	ΔC_5	ΔC_6
$0.05 \xi_L - 0.01 \xi_R$	$-0.14 \xi_L + 0.008 \xi_R$	$0.029 \xi_L - 0.017 \xi_R$	$-0.162 \xi_L + 0.01 \xi_R$
ΔC_7	ΔC_8	ΔC_9	ΔC_{10}
$0.036 \xi_L - 3.65 \xi_R$	$0.01 \xi_L - 1.33 \xi_R$	$-4.41 \xi_L + 0.04 \xi_R$	$0.99 \xi_L - 0.005 \xi_R$

TABLE I: Values of the new Wilson coefficients at the m_b scale.

Thus one can obtain the new contribution to the transition amplitude

$$\begin{aligned} \sqrt{2}A(\bar{B}^0 \rightarrow \pi^0 \bar{K}^0) = & A_{\pi^0 K^0}^{SM} - \lambda_t \left(A_{\pi \bar{K}} (-\Delta\alpha_4 + \frac{1}{2}\Delta\alpha_{4,EW} - \Delta\beta_3 + \frac{1}{2}\Delta\beta_{3,EW}) \right. \\ & \left. + \frac{3}{2}A_{\bar{K}\pi}\Delta\alpha_{3,EW} \right), \end{aligned} \quad (18)$$

$$\begin{aligned} \sqrt{2}A(B^- \rightarrow \pi^0 K^-) = & A_{\pi^0 K^-}^{SM} - \lambda_t \left(\frac{3}{2}A_{\bar{K}\pi}\Delta\alpha_{3,EW} \right. \\ & \left. - A_{\pi \bar{K}}(\Delta\alpha_4 + \Delta\alpha_{4,EW} + \Delta\beta_3 + \Delta\beta_{3,EW}) \right) \end{aligned} \quad (19)$$

and

$$A(\bar{B}^0 \rightarrow \pi^+ K^-) = A_{\pi^- K^+}^{SM} - \lambda_t A_{\pi \bar{K}} \left(\Delta\alpha_4 + \Delta\alpha_{4,EW} + \Delta\beta_3 - \frac{1}{2}\Delta\beta_{3,EW} \right), \quad (20)$$

where A^{SM} 's are the corresponding SM amplitudes as given in Eqs. (7-9) and $\Delta\alpha_i$'s and $\Delta\beta_i$'s are related to the new Wilson coefficients ΔC_i 's. Analogous to Eq. (11) we can now represent the transition amplitude incorporating the new physics contribution as

$$A(\bar{B} \rightarrow \pi \bar{K}) = A^{SM} - \lambda_t \xi A^N = \lambda_c A_c \left[1 + ra e^{i(\delta_1 - \gamma)} - r'b e^{i(\delta_2 + \phi_s)} \right], \quad (21)$$

where for simplicity we have assumed $\xi_L = \xi_R = \xi$. A^N is the new physics contribution which contains the strong phase information, $b = |\lambda_t \xi / \lambda_c|$, $r' = |A^N / A_c|$, and δ_2 is the relative strong phases between A^N and A_c . Thus from the above amplitude one can obtain the CP averaged branching ratio, direct and mixing induced CP asymmetry parameters as

$$\begin{aligned} \text{Br} &= \frac{|p_{c.m}| \tau_B}{8\pi M_B^2} \left[\mathcal{R} + 2ra \cos \delta_1 \cos \gamma - 2r'b \cos \delta_2 \cos \phi_s - 2rr'ab \cos(\delta_2 - \delta_1) \cos(\gamma + \phi_s) \right], \\ A_{\pi K} &= \frac{2 \left[ra \sin \delta_1 \sin \gamma + r'b \sin \delta_2 \sin \phi_s + rr'ab \sin(\delta_2 - \delta_1) \sin(\gamma + \phi_s) \right]}{\left[\mathcal{R} + 2ra \cos \delta_1 \cos \gamma - 2r'b \cos \delta_2 \cos \phi_s - 2rr'ab \cos(\delta_2 - \delta_1) \cos(\gamma + \phi_s) \right]}, \\ S_{\pi K} &= \frac{X}{\mathcal{R} + 2ra \cos \delta_1 \cos \gamma - 2r'b \cos \delta_2 \cos \phi_s - 2rr'ab \cos(\delta_2 - \delta_1) \cos(\gamma + \phi_s)}, \end{aligned} \quad (22)$$

where $\mathcal{R} = 1 + (ra)^2 + (r'b)^2$ and

$$\begin{aligned} X &= \sin 2\beta + 2ra \cos \delta_1 \sin(2\beta + \gamma) - 2r'b \cos \delta_2 \sin(2\beta - \phi_s) + (ra)^2 \sin(2\beta + 2\gamma) \\ &+ (r'b)^2 \sin(2\beta - 2\phi_s) - 2rr'ab \cos(\delta_2 - \delta_1) \sin(2\beta + \gamma - \phi_s). \end{aligned} \quad (23)$$

In order to see the effect of Z' boson, we have to know the values of the ξ or equivalently B_{sb}^L and $B_{dd}^{L,R}$. Generally one expects $g'/g_1 \sim 1$, if both the $U(1)$ gauge groups have the same origin from some grand unified theories. It has been shown in [17, 18] that the mass difference of $B_s - \bar{B}_s$ mixing and the CP asymmetry anomaly in $B \rightarrow \phi K, \pi K$ can be resolved if $|B_{sb}^L B_{ss}^{L,R}| \sim |V_{tb} V_{ts}^*|$. Assuming the universality of first two generations one can obtain $B_{dd}^{L,R} \simeq B_{ss}^{L,R}$ and hence $|\xi| \approx (M_Z / M_{Z'})^2$. The Z' mass is constrained by direct searches at Fermilab, weak neutral current data and precision studies at LEP [23], which give a model dependent lower bound around 500 GeV. Here we consider more conservative limit as $M_{Z'} \geq 700$ GeV, which gives the upper bound of the parameters $|\xi| < 1.65 \times 10^{-2}$. However, in this analysis we vary its value within the range (0.015 – 0.005), which is true for a TeV range Z' boson. For a heavy massive Z' boson (say $M_{Z'} > 1.5$ TeV) the new physics contributions is found to be very small and it does not have much impact on the SM results.

Now varying $|\xi|$ in the range $0.005 \leq |\xi| \leq 0.015$, we show in Figure-2 the correlation plots between $S_{\pi^0 K_s}$ and the branching ratio (left panel) and $S_{\pi^0 K_s}$ and $A_{\pi^0 K_s}$ in the right panel. The allowed region in $\Delta A_{CP}(K\pi)$ and $|\xi|$ plane is shown in the figure-3. From these figures it can be seen that the branching ratio and the CP violating parameters in $B^0 \rightarrow \pi^0 K^0$ mode and the $\Delta A_{CP}(K\pi)$ puzzle can be simultaneously explained in the model with an extra Z' boson.

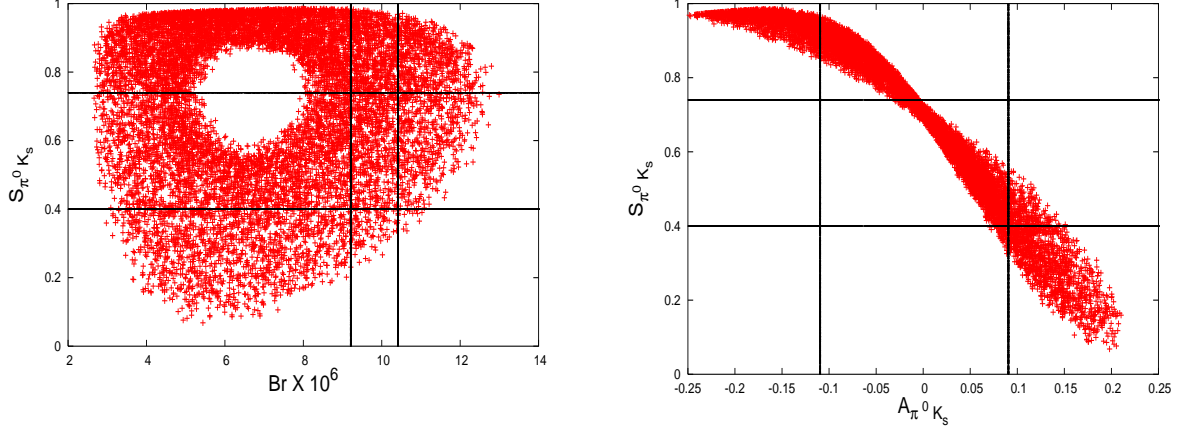


FIG. 2: Correlation Plots (a) between the mixing induced CP asymmetry $S_{\pi^0 K_s}$ and the direct CP asymmetry $A_{\pi^0 K_s}$ (b) between CP averaged BR and $S_{\pi^0 K_s}$ for the $B^0 \rightarrow \pi^0 K_s$ in the model with an extra Z' boson. The horizontal and vertical lines represent 1-sigma experimental allowed ranges.

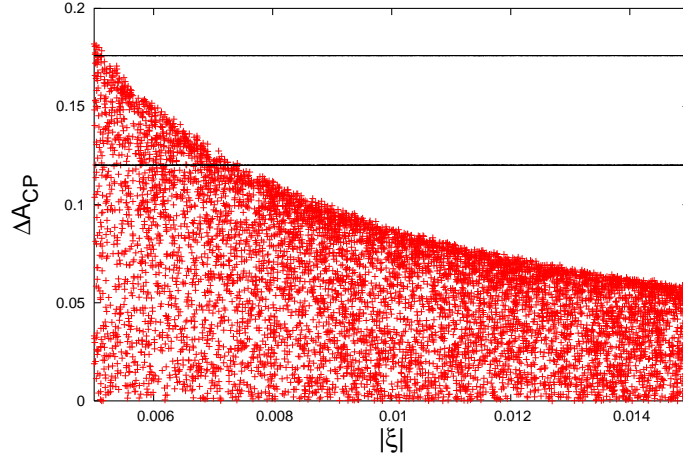


FIG. 3: The allowed region of the CP asymmetry difference (ΔA_{CP}) in the ($\Delta A_{CP} - |\xi|$) plane. The horizontal lines correspond to the experimentally allowed $1 - \sigma$ range.

It is well known that strangeness changing charmless B decays, dominated by $b \rightarrow s$ penguin amplitudes, which arise in the SM at one-loop level, are highly sensitive to new physics effects. Possible existence of new physics in these modes is being intensively searched via the measurement of time dependent CP asymmetries of neutral B meson decays into final CP eigen states. Virtual new heavy particles with mass scale typically around a TeV range may affect the SM predictions $A_{CP} \approx 0$ and $S_{CP} \approx \eta_{CP} \sin 2\beta$. Mixing induced CP

asymmetries measured in many $b \rightarrow s\bar{q}q$ modes give the trend $S_{s\bar{q}q} < \sin 2\beta$.

In this paper we have studied the $B \rightarrow K\pi$ decay modes, which receive dominant contributions from $b \rightarrow s$ QCD penguins in the SM. In the SM its mixing induced CP violation parameter in $B^0 \rightarrow K^0\pi^0$ is expected to be larger than that of $\sin 2\beta$, obtained from $b \rightarrow c\bar{c}s$ transitions and $\Delta A_{CP}(K\pi) \approx 2.5\%$. However the observed value $S_{\pi^0 K_s}$ is less than $\sin 2\beta$ by nearly 1-sigma and $\Delta A_{CP}(K\pi)$ deviates from its SM value by nearly 4σ . Also the SM predicted branching ratio in $B^0 \rightarrow \pi^0 K^0$ is found to be less than that of observed value. Since the final π^0 can materialize from a Z' boson, this decay mode is quite sensitive to electroweak penguin contributions. We have considered the effect of an extra non-universal Z' gauge boson which is expected to give significant contributions to electroweak penguin sector. We have shown that the observed anomalies in this mode could be successfully explained with a TeV range Z' boson. In future with improved statistics, this mode can provide an indirect hint for the existence of Z' boson.

Acknowledgments

The work of RM was partly supported by Department of Science and Technology, Government of India, through grant Nos. SR/S2/HEP-04/2005 and SR/S2/RFPS-03/2006. AG would like to thank Council of Scientific and Industrial Research and Department of Science and Technology, Government of India, for financial support.

-
- [1] Heavy Flavor Averaging Group, <http://www.slac.stanford.edu/xorg/hfag>.
 - [2] Y. Grossman and M. Worah, Phys. Lett. B **395**, 241 (1997); D. London and A. Soni, Phys. Lett. B **407**, 61 (1997).
 - [3] C. W. Chiang, M. Gronau, J. L. Rosner and D. A. Suprun, Phys. Rev. D **70**, 034020 (2004).
 - [4] M. Beneke, Phys. Lett. B **620**, 143 (2005).
 - [5] H. Y. Cheng, C. K. Chua and A. Soni, Phys. Rev. D **72**, 014006 (2005).
 - [6] G. Buchalla, G. Hiller, Y. Nir and G. Raz, JHEP **09**, 074 (2005).
 - [7] R. Fleischer, S. Jäger, D. Pirjol and J. Zupan, arXiv:0806.2900 [hep-ph].
 - [8] M. Gronau and J. L. Rosner, Phys. Lett. B **666**, 467 (2008).

- [9] I. Adachi *et al* [Belle Collaboration], arXiv:0809.4366 [hep-ex].
- [10] B. Aubert *et al* [Babar Collaboration], arXiv:0809.1174 [hep-ex].
- [11] E. Lunghi and A. Soni, JHEP **0709**, 053 (2007).
- [12] P. Langacker and M. Plümacher, Phys. Rev. D **62**, 013006 (2000); P. Langacker, hep-ph/0308033.
- [13] Y. Nir, D. J. Silverman, Phys. Rev. D **42**, 1477 (1990); E. Nardi, Phys. Rev. D **48**, 1240 (1993); V. Barger, M. S. Berger and R. J. Phillips, Phys. Rev. D **52**, 1663 (1995); T. Rizzo, Phys. Rev. D **59**, 015020 (1999).
- [14] M. Beneke and M. Neubert, Nucl. Phys. B **675**, 333 (2003).
- [15] C. Amsler *et al.*, Particle Data Group, Review of Particle Physics, Phys. Lett. B **667**, 1 (2008).
- [16] V. Barger, C. W. Chiang, P. Langacker and H. S. Lee, Phys. Lett. B **580**, 186 (2004).
- [17] V. Barger, C. W. Chiang, P. Langacker and H. S. Lee, Phys. Lett. B **598**, 218 (2004).
- [18] V. Barger, C. W. Chiang, J. Jiang and P. Langacker, Phys. Lett. B **596**, 229 (2004).
- [19] T. G. Rizzo, hep-ph/0610104; P. Langacker, arXiv:0801.1345 (hep-ph).
- [20] X. G. He and G. Valencia, Phys. Rev. D **74**, 013011 (2006); C. W. Chiang, N. G. Deshpande and J. Jiang, JHEP **08**, 075 (2006).
- [21] B. Mawlong, R. Mohanta and A. K. Giri, Phys. Lett. B **668**, 116 (2008).
- [22] G. Buchalla, A. J. Buras and M. Lautenbacher, Rev. Mod. Phys. **68**, 1125 (1996).
- [23] F. Abe *et al.*, [CDF Collaboration], Phys. Rev. Lett. **79**, 2192 (1997); J. Erler and P. Langacker, Phys. Lett. B **456**, 68 (1999); Phys. Rev. Lett. **84**, 212 (2000); LEP Electroweak Working Group, SLD Heavy Flavour Group, hep-ex/0212036.